Is Cognitive Science Truly Interdisciplinary?: The Case of Interdisciplinary Collaborations

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Abstract

The field of cognitive science is inherently multidisciplinary. However, it is unclear to what extent truly interdisciplinary work occurs in cognitive science. That is, is cognitive science merely a collection of researchers from different disciplines working separately on common problems? Data gathered from a recent cognitive science conference are presented. Interestingly, a significant proportion of interdisciplinary collaborations were found. Analyses were also conducted on the impact of same vs. different backgrounds on the structure of collaborations, and it was found that interdisciplinary collaborations involved more equally distributed contributions among the authors than did intradisciplinary collaborations.

Introduction

What is cognitive science? In their article, "Foundations of Cognitive Science," Simon and Kaplan (1989) define cognitive science as "the study of intelligence and intelligent systems, with particular reference to intelligent behavior as computation (p. 1)." Other definitions might include the particular class of problems that cognitive scientists study (e.g., memory, reasoning, problem solving, language processing, etc...). Whatever the definition of the particular content areas under investigation, it is clear that cognitive science is inherently interdisciplinary. In fact, the journal *Cognitive Science* has the following subtitle: "A multidisciplinary journal of artificial intelligence, linguistics, neuroscience, philosophy, psychology". Similarly, the bulletin board Netnews.sci.cognitive has the following definition in its first post: "Cognitive science is an interdisciplinary investigation of cognition, involving cognitive psychology, artificial intelligence, computer science, human-computer interaction, philosophy of mind, philosophy of science, linguistics, neuroscience, cognitive anthropology and other disciplines."

Thus, at its core, cognitive science is defined as being interdisciplinary. However, there are two senses in which a field may be interdisciplinary, and it is unclear in which sense cognitive science is interdisciplinary. In the first sense, researchers from various disciplines work on related issues, and publish in the same journals, but they do not work together on the same research projects, nor do they use methodologies from multiple disciplines on the same projects. For example, a computer scientist might present a model of language processing at a cognitive science conference without regard to human data or linguistic theory. Conversely, a psychologist might present data from a language processing experiment at a cognitive science conference without discussing its relation to linguistic theory or computational models of language processing. In both cases, scientists from different areas are working on related problems, and are presenting at the same conference. However, they are working on separate projects, and they are using separate, discipline-specific methodologies. We call this type of work *weakly interdisciplinary*.

In the second sense of interdisciplinary, researchers from various disciplines work together on the same projects or they use methodologies from multiple disciplines on the same research projects. For example, a computer scientist and a psychologist might present a simulation of language processing and an experiment designed to test the predictions of the simulation in human subjects. Alternatively, a psychologist might present data from psychological experiments of language processing, but also discuss the implications of the experiments for current models of language processing. We call this type of work *strongly interdisciplinary*. When there is a significant proportion of strongly interdisciplinary work in an field, the field becomes more than just the sum of its constituent disciplines.

We take the goal of cognitive science to involve strongly interdisciplinary work. In the information to authors section of the journal of *Cognitive Science*, it is made clear that "Reports written for multidisciplinary audiences are given the highest priority." However, desire does not equal reality: departments can often be insular; receiving training from other departments during graduate studies can often be difficult because of bureaucratic barriers or a lack of introductory courses; and communication across departments is often minimal. Thus, more evidence needs to be gathered to demonstrate that cognitive science is as it was created to be—strongly interdisciplinary.

As partial evidence that cognitive science involves some strongly interdisciplinary work, many institutes and departments of cognitive science have been created over the last 15 years, supposedly providing a research environment supportive of interdisciplinary work. However, the majority of work in cognitive science is not conducted at such places. Of articles published in the last two years in the journal of *Cognitive Science*, only 9% (3 of 35) articles involved authors from departments or institutes of cognitive science. For the Annual Meeting of the Cognitive Science Society of the last two years, only 11% (22 of 165 for the 1994 meeting, and 15 of 157 for the 1993 meeting) of the papers involved work conducted at departments or institutes of

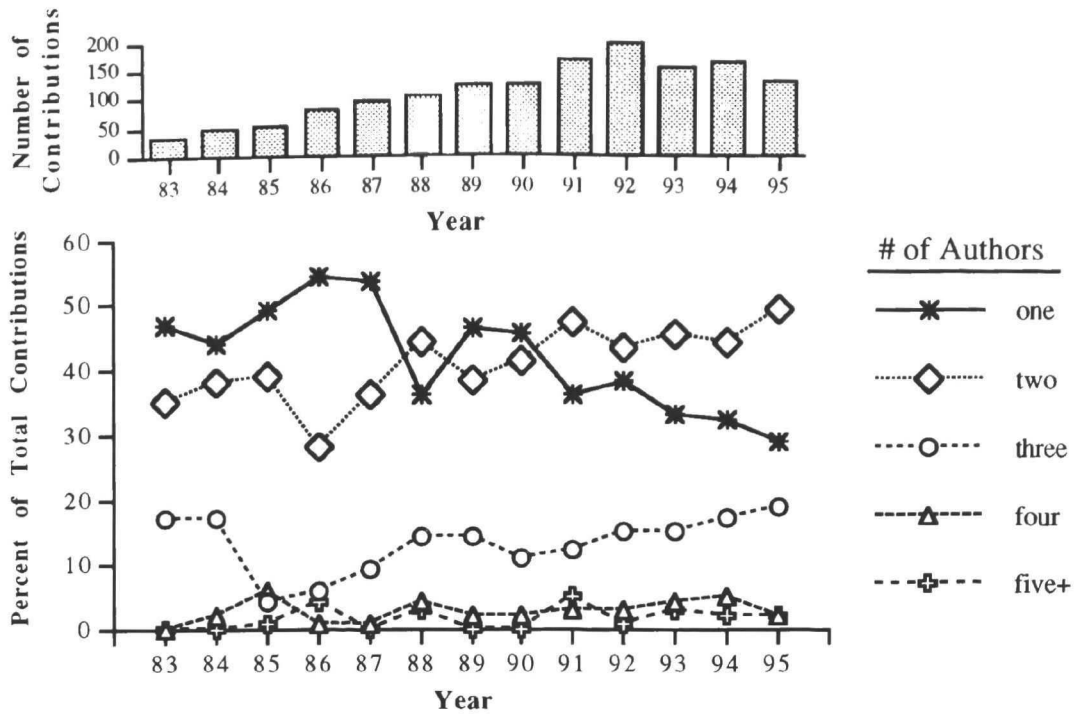

Figure 1: The total number of submitted papers and posters for each Annual Meeting of the Cognitive Science Society, and the percentage of papers at each author level.

cognitive science. Thus, despite the existence of departments of cognitive science, the majority of cognitive science researchers still reside within the more traditional departments, and are consequently subject to problems of insularity from other work conducted in other disciplines.

Another test for the presence of strongly interdisciplinary work is the existence of interdisciplinary collaborations. Collaborations in general have formed an increasingly important role in the sciences over the last 100 years (Thagard, 1994). Over the somewhat briefer history of cognitive science, collaborations have also grown in frequency. Figure 1 presents the percentage of multi-author papers and posters presented at each Annual Meeting of the Cognitive Science Society for the last thirteen years (as well as the total number of papers and posters presented).[1] We only present data from 1983 on, since 1983 is the first year in which submissions were reviewed. From the figure, it is evident that the period from 1983 to 1995 represents a significant growth period in cognitive science—the number of papers in the conference grew approximately fourfold over the thirteen years. In that time, proportion of multi-author papers grew gradually by twenty percent. The decrease in single author papers (and therefore increase in multi-author papers) was statistically significant ($t(11)=4.4$, $p<.002$). Moreover, over the thirteen years, the model number of authors has gone from one author to two authors. Thus, collaborations, for whatever reason, are a dominant feature of work in cognitive science.

Although there are a significant number of collaborations in cognitive science, it is unclear how many of them are interdisciplinary. The growth in the number of collaborations in cognitive science could simply reflect the growth in intradisciplinary collaborations that is occurring in each of the component disciplines rather than a growth in interdisciplinary collaborations. Since the majority of the research was conducted in traditional departments rather than interdisciplinary institutes, it would not be surprising if there were few interdisciplinary collaborations—physical proximity is a strong factor in the occurrence of collaborative research (Kraut, Egido, & Galegher, 1990).

The primary goal of the research presented in this article is to assess the presence of interdisciplinary collaborations in cognitive science. However, another reason for being interested in interdisciplinary collaborations is the role they play in science in general. Various researchers in the psychology of science have argued that interdisciplinary collaborations are more likely to be successful than intradisciplinary collaborations. For example, Dunbar (1994; Dunbar & Baker, in press) found that microbiology laboratories were more likely to make progress on the problems they were investigating when the laboratories were composed of researchers from different backgrounds than when the laboratories were composed of researchers from the same background. Dunbar argued that having different backgrounds provided a larger database of experience that could be applied analogically to the current problems under study. Similarly, in a review of several historical cases, Okada (1994) argued that highly successful collaborations in science typically involved researchers from different backgrounds (see also Okada, Schunn, Crowley, Oshima, Miwa,

[1] These figures included submitted papers and posters only. Symposia and invited papers were not included

Aoki, & Ishida, 1995). Thus, a secondary goal of the research presented here is to investigate further the impact of interdisciplinary collaboration on the research project. The primary goal is about cognitive science in particular, and the secondary goal is about the nature of scientific collaborations in general.

The methodology used in our study involved a questionnaire given to conference presenters. To gather information about backgrounds of collaborators, we did not wish to rely on a simple analysis of affiliations listed in the conference proceedings—departmental affiliations are not necessarily good indicators of training backgrounds, especially in the case of multidisciplinary departments and institutes. Instead, we gathered information about the training backgrounds of the members of collaborative research projects. This information was gathered through interviews with authors of multi-author papers presented at a recent Cognitive Science Society meeting.

There is one further factor that deserves some discussion: not all collaborations are of the same type. Of particular relevance to our study, not all collaborations involve equal-status individuals. Instead, some collaborations involve employer/employee and teacher/student collaborations. It may be that the nature of these different-status collaborations is unlike that of the equal-status collaborations. In particular, these collaborations are less likely to be interdisciplinary, since students usually work with professors from their own department. To investigate the potential role of these different types of collaborations, we added professional level to all of the analyses.

Methods

Overview

The study consisted of two methods of data collection. The first method involved short interviews with the first authors of posters during the poster session. The second method involved questionnaires sent to the first authors of papers and panel posters.[2] Subjects were asked about the backgrounds of each of the authors of the presented work, and about the professional status of each author. Subjects were also asked about the role each of the authors played in the various stages of the research presented at the conference.

Participants

All participants were paper and poster presenters at the 16th Annual Meeting of the Cognitive Science Society held in Atlanta, GA on August 13-16, 1994. Permission to conduct the study was obtained from the conference organizers.

There were 29 multi-author posters in the traditional poster session. All first authors were contacted by electronic mail to ask for permission to interview them during the poster session. Twenty (69%) of the first authors responded, all in the affirmative.[3] However, due to time restrictions, only 17 of the interviews were conducted.

There were 83 papers and panel posters with multiple authors. All first authors were sent a short questionnaire by E-mail. Fifty-three (64%) were completed and returned.

Procedure

Poster interviews. The first authors of multi-author poster presentations were contacted in advance of the conference by E-mail. Participants were given a brief description of the purpose of the study. They were also informed the study was not an official activity of the conference, and they were under no obligation to participate. Further, they were informed that all responses would be kept confidential.

At the conference, participants were approached during the poster session when they had a spare moment. The interviews were approximately five minutes in length. During the interview, the participants were asked questions about each of the authors of the poster. The first question inquired about which area was the primary background or training of each author (e.g., computer science, linguistics, psychology, medicine, philosophy, etc...).[4] The second question inquired about the professional status of each author as the presented research was being conducted (e.g., research assistant, undergraduate, graduate, post-doc, faculty, clinician, etc...). The third and final question was about the role each author played in the research project. In particular, the participants were asked which authors had played a major role in each of the following categories: (a) selecting the research question; (b) designing the study or simulation; (c) providing the materials for the study or simulation; (d) running the studies or simulations; and (e) writing the paper.

E-mail questionnaires. The first authors of multi-author papers and panel posters were contacted one month after the conference by E-mail. As with the poster interviews, the participants were given a brief description of the purpose and nature of the study. Further, they were also informed that the study was not an official activity of the conference, that they were under no obligation to participate, and that all responses would be kept confidential. At the end of the mail message, they were presented with a questionnaire version of the questions given in the poster interviews. Participants were asked to complete the questionnaire, and respond by E-mail.

Coding

Since there were only two papers with more than 4 authors, only the data for the first 4 authors of each paper were coded. Responses to the background questions were classified into the following categories (with frequencies): cognitive psychology (86), computer science (54), linguistics (11), educational psychology (5), engineering (4), philosophy (3),

[2] This particular conference involved special panel poster sessions in addition to the traditional poster session. In these special sessions, thematic groups of presentations were presented together, and were followed by a discussant.

[3] In four cases, it was the second author who presented the poster and granted permission for the interview.

[4] Here we focus on the case of interdisciplinary collaborations. We will consider the case of collaborations involving collaborators with different backgrounds within the same discipline in the discussion.

medicine (3), mathematics (3), cognitive engineering (1). When two background disciplines were listed, the first discipline listed was used. When cognitive science was the first discipline listed, the secondary discipline listed was used. Responses to the professional status questions were classified into one of four levels (with frequencies): research assistant/undergraduate (10), graduate (63), postdoctoral fellow/junior researcher (15), faculty/senior researcher/clinician (86). These professional status levels were used to determine whether collaborations were equal status or different status collaborations.

For the research roles question, an author was considered to have made a contribution to one of the categories if they were listed in that category, unless some note added that they had made only a minor contribution to that category. Then, the number of research roles to which each author contributed was tabulated. For example, if author A chose the research question, designed and ran the experiment, and wrote the paper, whereas author B provided the materials, and helped write the paper, then author A would be counted as having contributed to 4 roles and author B would be counted as having contributed to 2 roles. The distribution of number of roles assigned to authors (independent of authorship order) is presented in Table 1. The mean number of roles assigned to each author was 2.8 (SD=1.5).

Table 1: The frequency of number of roles assigned to each author independent of authorship order.

# of roles	0	1	2	3	4	5
frequency	11	27	31	38	44	22

Results & Discussion

Overview

The results are divided into two sections. In the first section, we assess the frequency of interdisciplinary collaborations. In the second section, we assess the structure of different collaboration types. Three variables are considered in both sections: testing format (interview/E-mail), professional level (same/different), and background (same/different).

Frequency of Interdisciplinary Collaborations

Do interdisciplinary collaborations occur frequently in cognitive science? Overall, 47% (33 of 70) of the collaborations at the conference were interdisciplinary (i.e., had authors from at least two disciplines). If only the first 2 authors are considered, 40% of collaborations were interdisciplinary. These percentages in conjunction with the overall rate of collaborative research imply that interdisciplinary collaborations represent approximately 32% of all contributions (i.e., individual and collaborative combined).

Another method of assessing the frequency of interdisciplinary collaborations is to use the departmental affiliations listed in the papers. Using this measure, 37% (41 of 112) of all the collaborative contributions to this conference involved interdisciplinary collaborations. This number is likely to be an underestimate of interdisciplinary collaborations given that some sets of collaborators listed interdisciplinary institutes as their primary affiliations. However, despite potential biases, this measure provides a similar order of magnitude estimate for the frequency of interdisciplinary collaborations in cognitive science.

What was the frequency of interdisciplinary collaborations across the various constituent disciplines? To answer this question, we analyzed how often each discipline was paired with each other discipline. For simplicity, only the first two authors were considered. All of the interdisciplinary collaborations involved either cognitive psychologists or computer scientists. Table 2 presents the frequency of each discipline combination (the middle two columns), as well as the frequency of intradisciplinary collaborations for comparison (the rightmost column). The order of authorship is not represented. Interestingly, all of the disciplines except for cognitive psychology had at least as many or more interdisciplinary than intradisciplinary collaborations.

Did interdisciplinary collaborations occur equally often for same level (peer) collaborations than for different level collaborations? One might expect same level collaborations are more likely to be interdisciplinary than different level collaborations. Surprisingly, the effect of professional level (same/different) on the frequency of interdisciplinary collaborations was not significant ($\chi^2(1)<1$, $p>.5$ considering all authors, and $\chi^2(1)<1$, $p>.4$ considering only the first two authors). That is, there was an overall high level of interdisciplinary collaborations, both for equal status and different status collaborations. However, there was a trend towards a greater number of interdisciplinary collaborations in equal-level collaborations than different-level collaborations (see Table 3).

Table 2: Interdisciplinary and intradisciplinary collaborations among the disciplines (between first and second authors).

Discipline	Interdisciplinary Collaborations w/ Cog Psychology	Interdisciplinary Collaborations w/ Computer Science	Intradisciplinary Collaborations
Cognitive Psychology		13	24
Computer Science	13		14
Educational Psychology	3	0	1
Linguistics	2	3	2
Philosophy	1	2	0
Medicine	1	1	0
Cognitive Engineering	1	0	0
Engineering	0	1	1

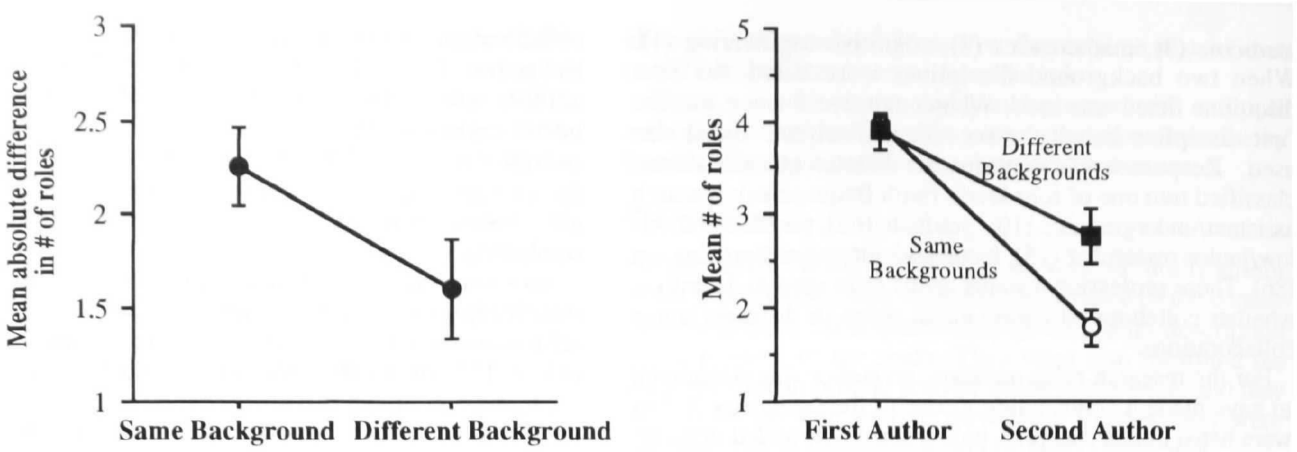

Figure 2: (a) The mean absolute difference in number of roles, and (b) the mean number of roles to which the first and second authors contributed as a function of whether the authors were from the same or different backgrounds (with SD).

Table 3: Frequency of inter & intradisciplinary collaborations for same & different level collaborations (with column percentages).

Background	Same Level	Different Level
Same	7 (50%)	35 (62%)
Different	7 (50%)	21 (38%)

Finally, we analyzed whether the results were consistent across the two testing formats. It was also surprising that there were more interdisciplinary collaborations in the interview condition than in the E-mail condition ($\chi^2(1)=4.96$, $p<.03$ considering all authors, and $\chi^2(1)=8.7$, $p<.005$ considering only the first two authors). In the E-mail condition, 40% of the collaborations involved at least two disciplines, whereas 71% did in the interview condition. It is likely that these differences are due to the type of presentation format rather than method of data collection. That is, the interviews involved posters from the general poster session, whereas the E-mail questionnaires involved panel posters and papers organized into thematic groups. Thus, the interdisciplinary collaborations were less likely to be classifiable into a simple category, and so they were more likely to be assigned to the general poster session. However, whatever the cause of the condition differences, there was a fairly high overall percentage of interdisciplinary collaborations.

The Effects of Interdisciplinary Collaborations

One would expect interdisciplinary collaborators to be more likely to have important independent contributions to the research project, since they are bringing non-overlapping knowledge to the research project. By contrast, in the case of intradisciplinary collaborations, the collaborators are not as likely to bring non-overlapping knowledge to the project. Since the rewards of research are linked to authorship order, there is some pressure for one of the collaborators to take a primary role.

As a result, we would expect interdisciplinary collaborators to contribute more equally to the research project than intradisciplinary collaborators, since equal contribution is more likely to be necessary (because of non-overlapping knowledge) in the interdisciplinary case.

Table 4: Mean (and SD) number of roles assigned to each author as a function of authorship order.

Order	1	2	3	4
# of roles	3.9 (.8)	2.2 (1.4)	1.9 (1.2)	2.0 (.6)

To test these hypotheses, we used the number of roles to which each author contributed as a measure of degree of contribution. As expected, overall there was an effect of authorship order on the number of roles ($F(3,170)=36.0$, $p<.0001$), with the first author contributing to the greatest number of roles (see Table 4).

To test the influence of collaboration make-up, we computed an ANOVA on the mean absolute difference in the number of roles to which the first and second authors contributed as a function of whether the first and second authors were from the same or different backgrounds (see Figure 2a).[5] Intradisciplinary collaborations had a significantly greater difference in the number or roles than interdisciplinary collaborations ($F(1,68)=3.9$, $p<.05$), confirming our expectations.

To test whether these results also held across testing formats (interview or E-mail), and professional level (same status vs. different status), further ANOVA's were conducted. There were no significant main effects of testing format ($F(1,62)<1$, $p>.9$) or professional level ($F(1,62)<1$, $p>.9$) on the mean difference in number of roles. Furthermore, there were no significant interactions of background with testing format ($F(1,62)<1$, $p>.4$), background with professional level ($F(1,62)<1$, $p>.6$), or testing format with professional level ($F(1,62)<1$, $p>.7$). Thus, the main effect of background held across both types of collaborations and data collection methods.

[5] The 3+ author case is difficult to analyze, since it is unclear which pairings of background types and role differences to include. However, since the first two authors are likely to be the primary contributors to the project, using only the first two authors is likely to be a good first approximation.

However, the preceding analyses do not indicate whether the first authors contributed less in the interdisciplinary collaborations, or whether the second authors contributed more in the interdisciplinary collaborations. To investigate this issue, a 2 (same background/different background) X 2 (first author/second author) ANOVA was conducted on the number of roles to which each author contributed (see Figure 2b). The background similarity by author order interaction was statistically significant ($F(1,68)=7.1$, $p<.01$)—there was no effect of background similarity on first author contributions, whereas there was an effect on second author contributions. Thus, the interdisciplinary collaborations involved an increased presence of the second authors.

General Discussion

The primary goal of this study was to investigate the presence of strongly interdisciplinary work in cognitive science. We found that there are, in fact, a significant proportion of interdisciplinary collaborations in cognitive science. Interestingly, there was almost as high a proportion of interdisciplinary teacher/student collaborations as interdisciplinary peer collaborations. While a simple survey of this type can not be conclusive, it is very suggestive: not only does cognitive science expose people to work from other disciplines, it involves strongly interdisciplinary work, suggesting that cognitive science is more than just the sum of its constituent disciplines.[6]

The secondary purpose of this study was to investigate the impact of the diversity of backgrounds among collaborators on the structure of the collaboration. Various researchers (e.g., Dunbar, 1994; Okada, 1994) in the area have hypothesized that collaborations among scientists with differing background knowledge are more likely to be successful than collaborations among scientists with the same background knowledge. We have found that interdisciplinary collaborations tend to be more balanced. In particular, we found that second authors tended to contribute more to interdisciplinary collaborations than to intra-disciplinary collaborations.

The findings of this study must be approached with caution due to the following methodological concerns: 1) we have used a very short and simple questionnaire; 2) data was only collected from the first authors; 3) relying on data from responses via E-mail may have biased the results (either in favor of E-mail literate researchers and/or in favor of researchers with an interest in interdisciplinary collaborations); and 4) number of roles to which an author contributes is a crude measure of intellectual input. However, as a first pass, this study has provided some suggestive and interesting data. Furthermore, a simple analysis of departmental affiliations found a similar order of magnitude of interdisciplinary collaborations.

We are currently seeking to replicate and extend our findings using more detailed investigations of collaborations. For example, in one study, we are focusing on famous collaborators, and are using in-depth interviews with both members of the collaborations. In another study, we are using more detailed questionnaires about ongoing collaborations (e.g., Okada, Schunn, Crowley, Oshima, Miwa, Aoki, & Ishida, 1995). In particular, we will be interested in whether background factors will predict future collaborations and collaborative success.

There is one further important issue that we have neglected thus far: what constitutes different backgrounds. While we have focused on the case of interdisciplinary collaborations, intradisciplinary collaborations may also involve collaborators with different backgrounds. These within-discipline training differences can result from studying different problems (e.g., categorization vs. language processing), or being trained at schools with different general approaches (e.g., case-based vs. rule-based reasoning). Thus, the same background/different background dimension is actually a continuum of background overlap. Further research is necessary to determine whether these within discipline differences have a similar impact on the structure of the collaboration.

[6]Whether this strong presence of interdisciplinary work is entirely representative of the work that is conducted or just of the work that is published remains to be seen.

Acknowledgements

This research was supported by a grant from the Mitsubishi Bank International Foundation to all three authors, and by a FCAR graduate fellowship to the first author. We would like to thank to Ashwin Ram for his assistance in the project, and to Beth Littleton and two anonymous reviewers for comments made on earlier drafts of this paper. We would also like to thank all those that participated in this study.

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